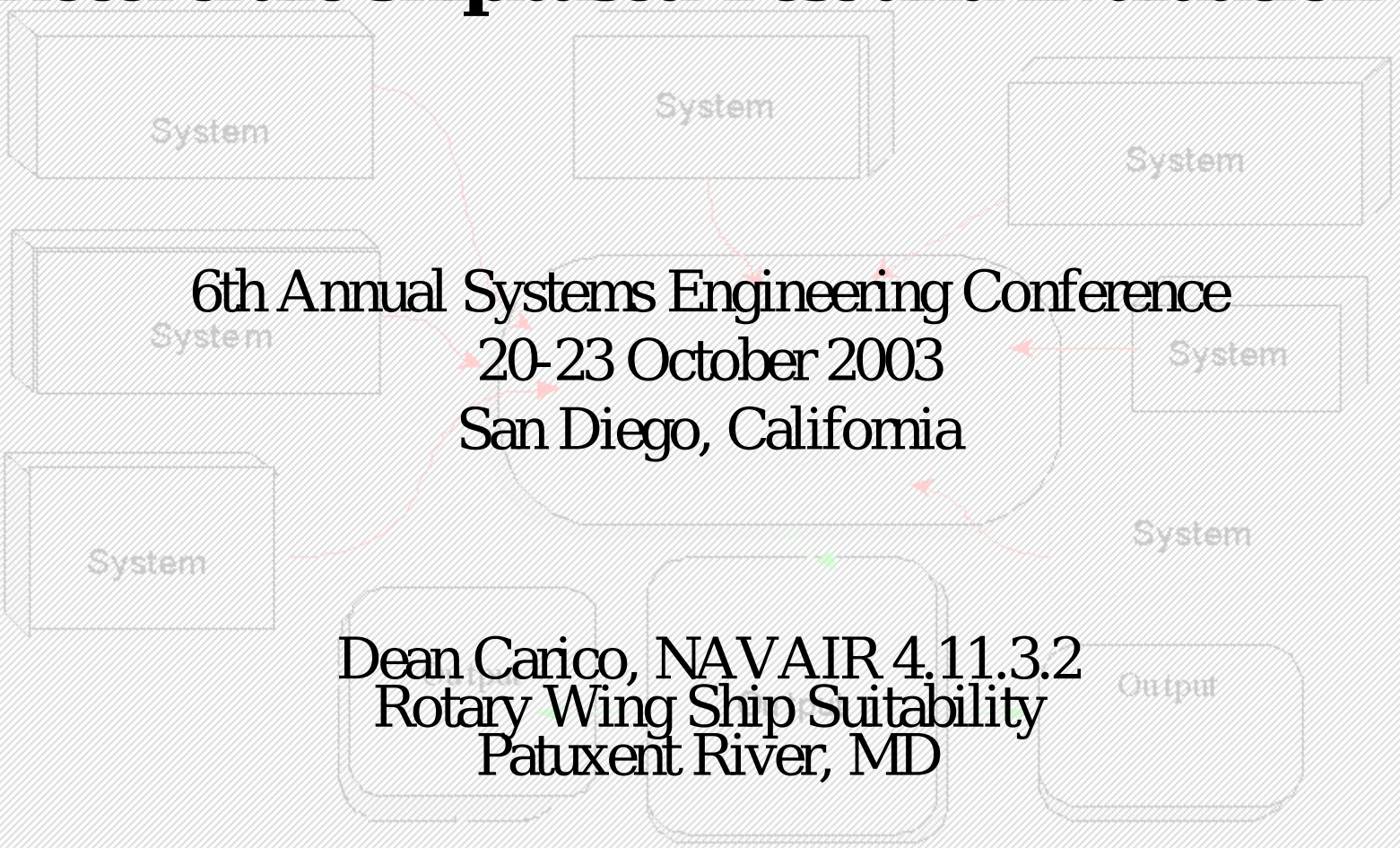
Virtual Systems Engineering Options to Support Rotorcraft Shipbased Test and Evaluation



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Dean Carico, NAVAIR 4.11.3.2
Rotary Wing Ship Suitability
Patuxent River, MD

OUTLINE

- T&E Overview
- Helicopter/Ship Testing
- Dynamic Interface Support Options
- SoS Approach
- Virtual Flight Test Support
- Summary

T&E Overview

- DoD Procurement Funds
- Current Cost of Rotorcraft Testing
  - Becoming more expensive
  - May uncover problems late in acquisition cycle
- Mission Rehearsal Training
  - OFT/WST Expensive
  - Far removed from battlefield site
- Acquisition & Mishap Investigations
  - Not integrated with flight testing

T&E Emphasis

- **Past – Cost and Cycle Time**
- **Current –Interoperability & SoS**
  - **Interoperability**
    - The ability of systems to provide services to and accept services from other systems
    - DoD 5000 series requires that all systems must be designed and tested to ensure interoperability
  - **System-of-Systems (SoS)**
    - A system working with a group of other systems or sub-systems in a seamless environment

T&E Options

- **Business as usual - Conventional T&E**
  - Introduction of personal computer in the 1980's
  - Introduction of the WWW in the 1990's
  - Cost & Cycle Time Problems
- **Combine Conventional T&E and Virtual** T&E using related technology options
  - Develop and validate a virtual capability to support and enhance conventional T&E

Land-Based Testing

- **US NAVY Test Pilot School** (Conventional T&E)
- **Helicopter Performance**
  - Hover, Level Flight, Climbs & Descent, Engine Assessment, &Airspeed/Altimeter Calibration
- **Flying Qualities**
  - Longitudinal, Lateral, & Directional Static & Dynamic Stability, Flight Control System, Rotor Characteristics & Open Loop Testing

T&E Environment Control

- **Land-Based – Can Control**
  - Use of highly instrumented aircraft
  - Test schedule
  - Repeat test as required
- **Ship-Based – Cannot Control**
  - Instrumentation in fleet aircraft
  - Test schedule (Usually plan well in advance)
  - Ambient winds and sea-state
  - Number of repeat tests required

NAVAIR

US Maritime Rotorcraft

(Approx # of squadrons, # per squadron)

US Navy Ships

USN = Approximately 300 total ships

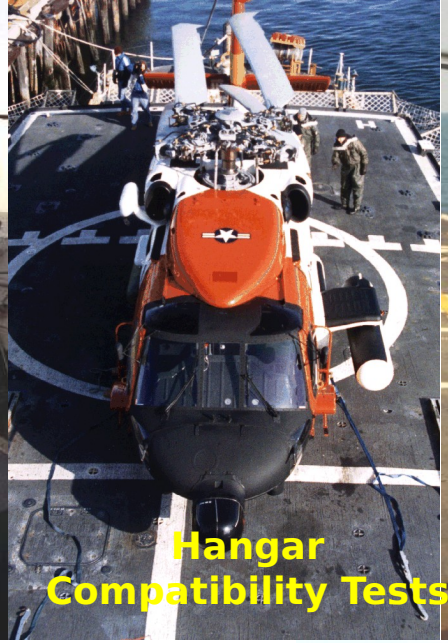
- 4 aircraft carrier classes ~ 13 ships
- 5 surface combatant classes ~ 141 ships
- 4 amphibious ship classes ~ 36 ships
- 20 support ship classes ~ 85 ships
- 9 non-helo capable classes ~ 40 ships
  - (+41 USCG cutters in wartime)

Dynamic Interface (DI) Rotorcraft/Ship Operational Challenges

Shipboard Rotorcraft Operation Environment

- High & Turbulent Winds
- Possible Low Visibility Condition
- Moving & Confined Landing Platform
- Unusual Airwake Over the Deck of Ship

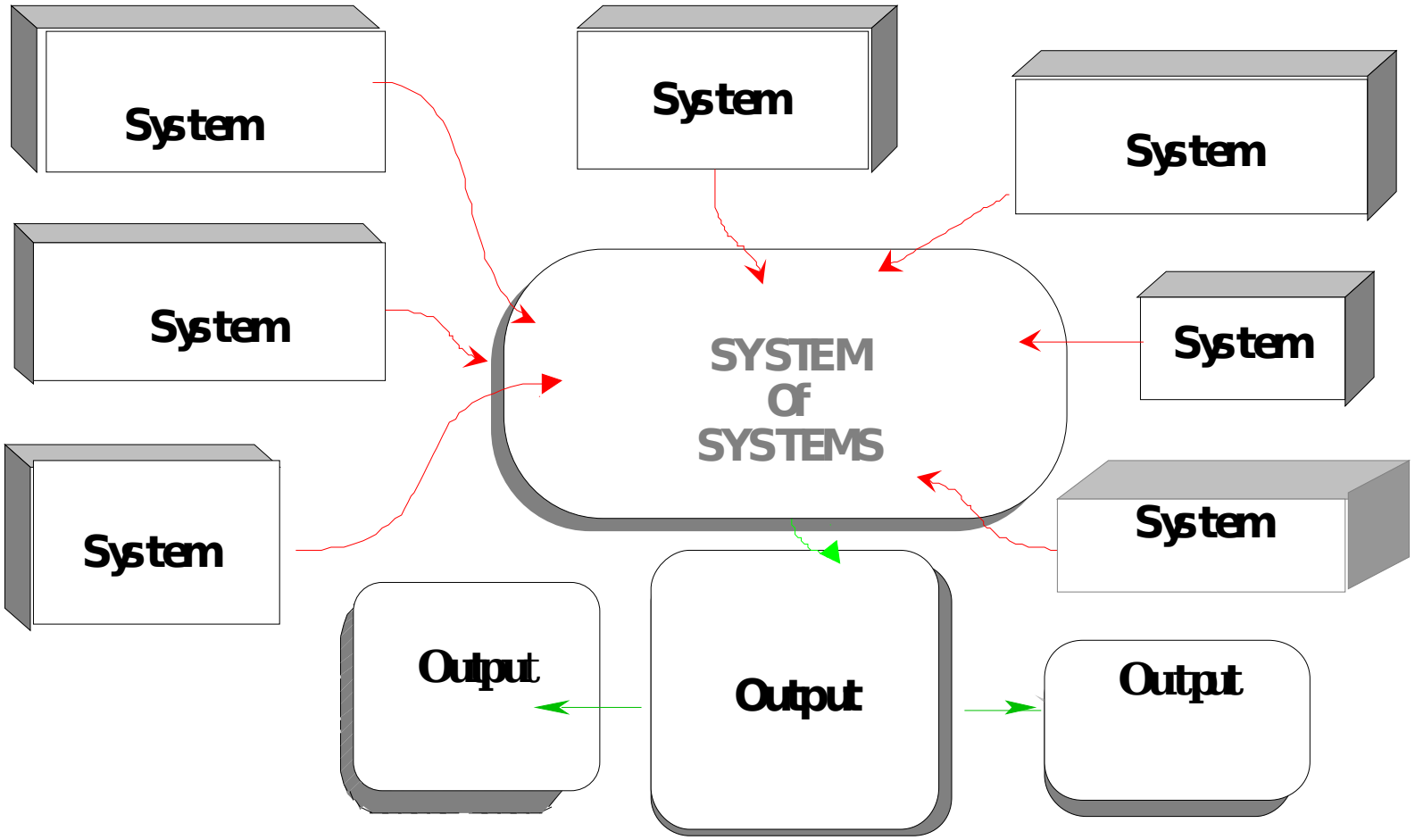
Helicopter/Ship Dynamic Interface Test Scope



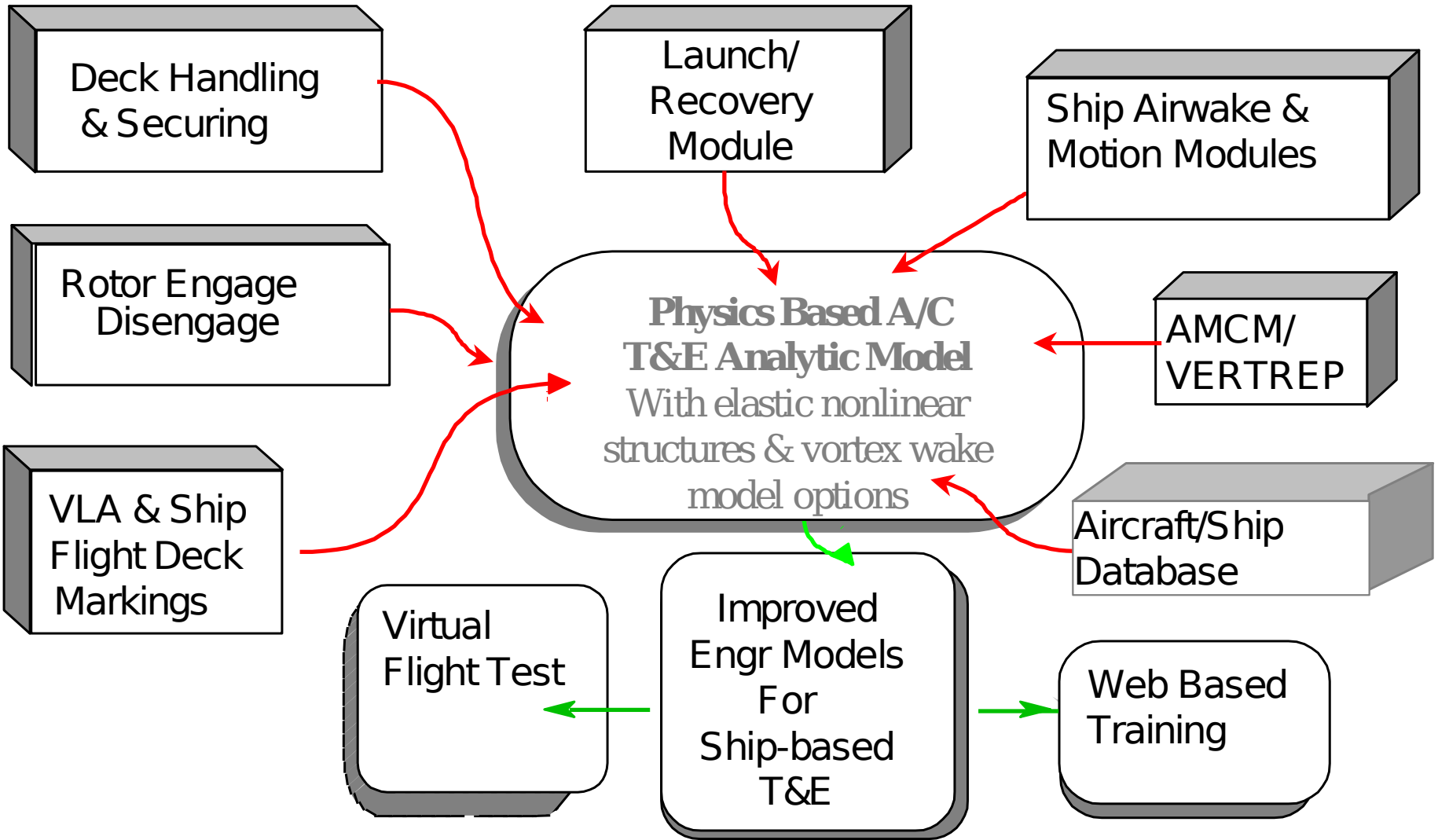
AIRCRAFT/SHIP TEST SYSTEMS

- **General**
  - Aircraft (Geometry, rotors, flight controls, etc)
  - Ship (Geometry, airwake, motion, deck layout)
- **Specific**
  - Day & Night Launch/Recovery
  - Helicopter Deck Handling/Securing
  - Rotor Engage/Disengage
  - Visual Landing Aids/Markings
  - Vertical Replenishment

System of Systems (SoS) Approach



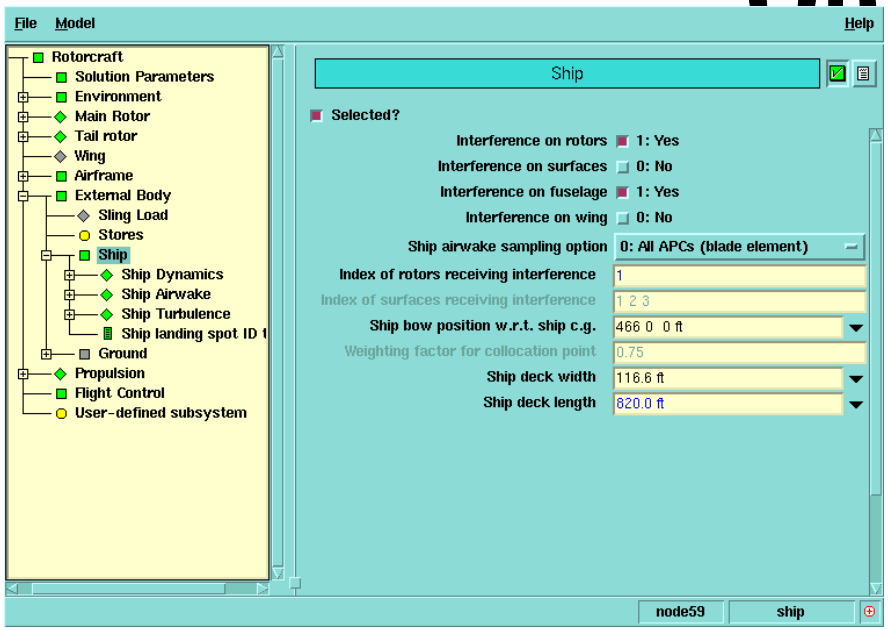
SoS DI T&E Approach

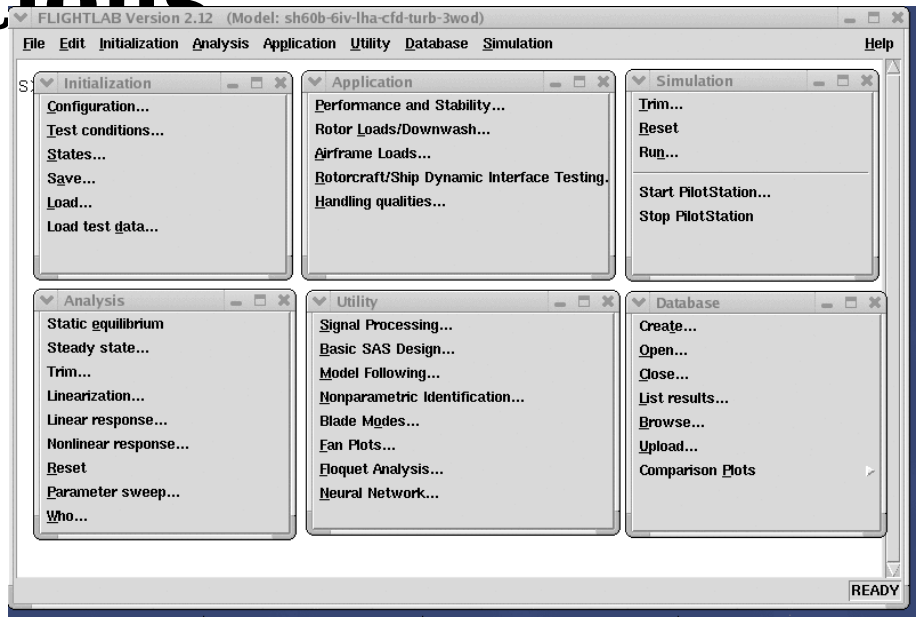

Deck Handling & Securing
Launch/ Recovery Module
Ship Airwake & Motion Modules
Rotor Engage Disengage
Physics Based A/C T&E Analytic Model
With elastic nonlinear structures & vortex wake model options
AMCM/ VERTREP
VLA & Ship Flight Deck Markings
Aircraft/Ship Database
Virtual Flight Test
Improved Engr Models For Ship-based T&E
Web Based Training

DI Analytic Options

- **Aircraft**
  - Comprehensive real & non-real time codes
  - Aircraft specific codes & reduced order models
- **Ship Airwake**
  - Computational Fluids Dynamics & Wind Tunnel
- **Ship Motion**
  - Navy Carderock Program & Summed Sine Waves
- **Integration Options**
  - Linear superposition
  - Loose & tight coupling

Virtual Flight Test Support Options





ID	Test Type	Test Conditions AS KCAS	Hp FT	OAT Deg C	Nr RPM	Test Configuration WT LBS	FSCG Inch	BLCG Inch	FCS Status 1/0	Others	Plot Options
	Hover	0	0	15	257.8	16308	360	0	1	Inputs...	Results...
	Critical Azimuth	20	0	15	257.8	16308	360	0	1	Inputs...	Results...
	Low Speed	0	0	15	257.8	16308	360	0	1	Inputs...	Results...
	Level Flight	40	0	15	257.8	16308	360	0	1	Inputs...	Results...
	Forward Climb	60	0	15	257.8	16308	360	0	1	Inputs...	Results...
	Lng Stat Stability	60	0	15	257.8	16308	360	0	1	Inputs...	Results...
	Lat Stat Stability	60	0	15	257.8	16308	360	0	1	Inputs...	Results...
	Lng Dyn Stability	60	0	15	257.8	16308	360	0	1	Inputs...	Results...
	Coordinated Turn	60	0	15	257.8	16308	360	0	1	Inputs...	Results...
	Autorotation	60	0	15	257.8	16308	360	0	1	Inputs...	Results...

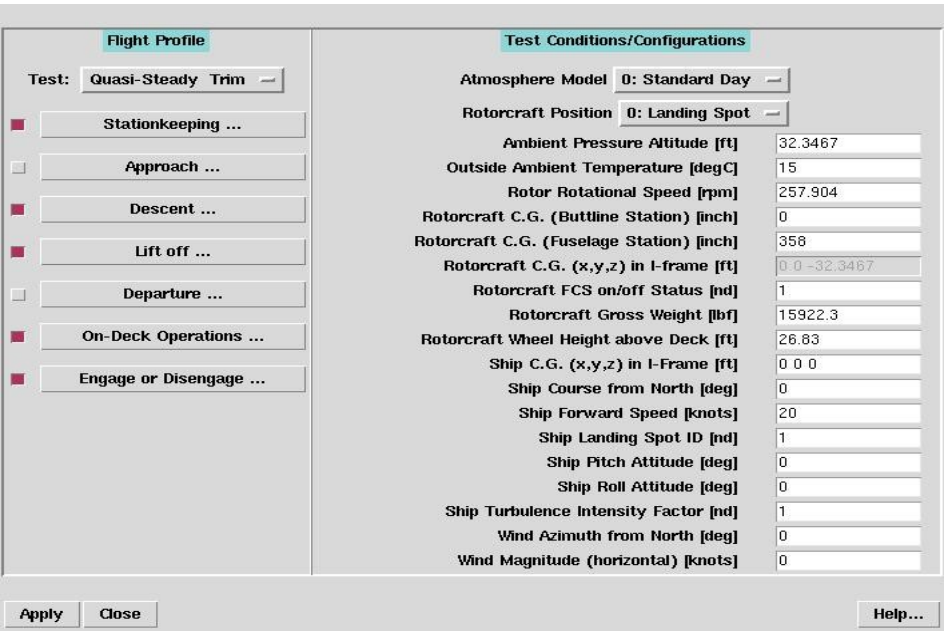
Run Reset Stop... Load... Save... Comparison... Close Help...

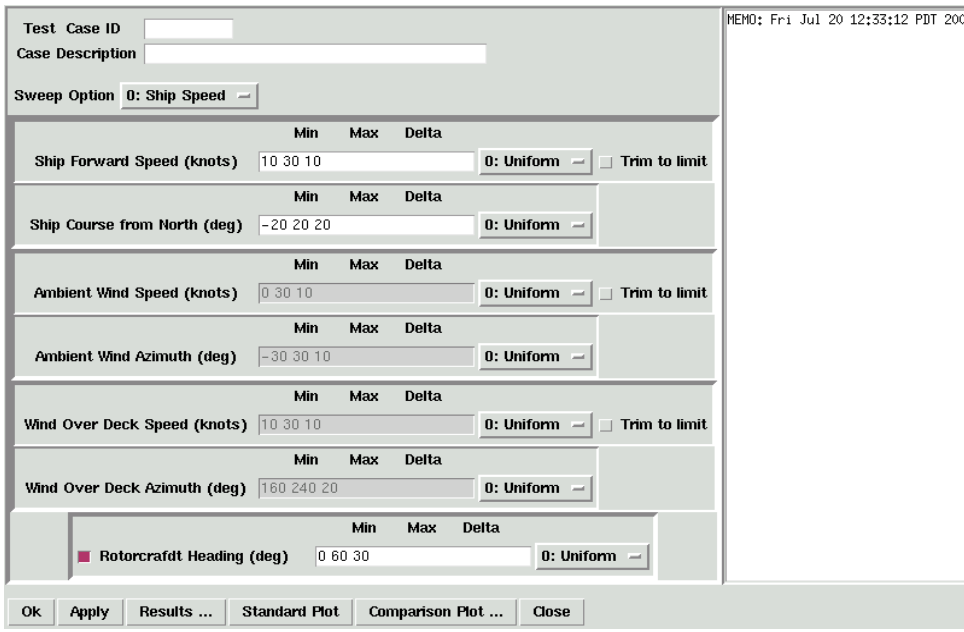
Input data option: ◆ Compute data (nonlinear) ◇ Compute data (linear)

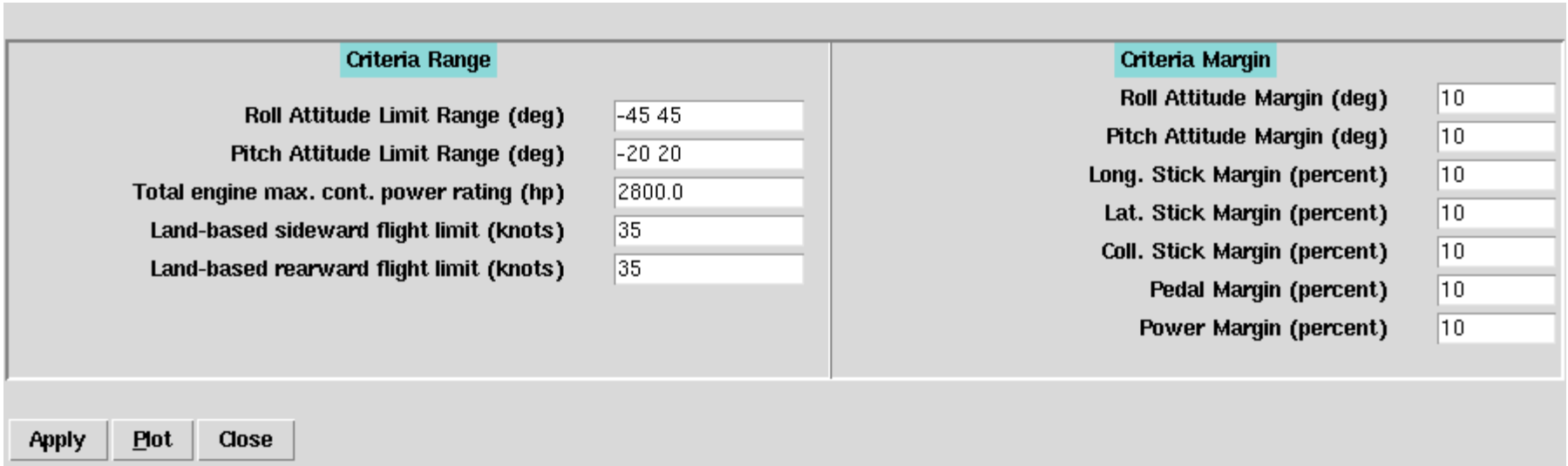
ID	Test Type	Test Conditions AS KCAS	Hp FT	OAT Deg C	Test Configuration WT LBS	FSCG Inch	BLCG Inch	Plot Options
	Damping	0	0	15	16269	360	0	Results...
	Quickness	0	0	15	16269	360	0	Results...
	Bandwidth	0	0	15	16269	360	0	Results...
	Bank Angle Oscillation	0	0	15	16269	360	0	Results...
	Pitch/Roll Oscillation	0	0	15	16269	360	0	Results...
	Lat-Dir Stability	50	0	15	16269	360	0	Results...
	Yaw-due-Collective	0	0	15	16269	360	0	Results...
	Torque Response	0	0	15	16269	360	0	Results...
	Turn Coordination	50	0	15	16269	360	0	Results...

Run Close help...

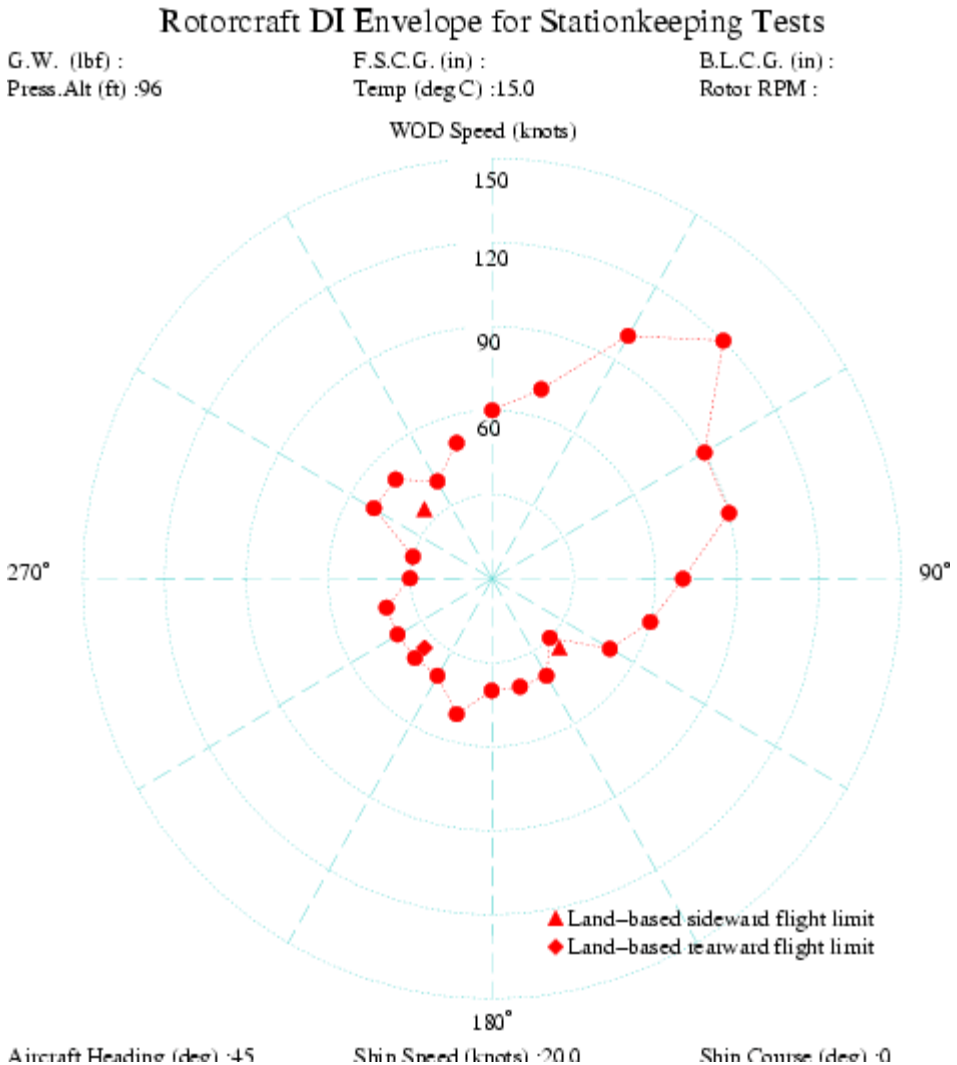
Dynamic Interface Support Options


Flight Profile
Test: Quasi-Steady Trim
Stationkeeping ...
Approach ...
Descent ...
Lift off ...
Departure ...
On-Deck Operations ...
Engage or Disengage ...
Test Conditions/Configurations
Atmosphere Model 0: Standard Day
Rotorcraft Position 0: Landing Spot
Ambient Pressure Altitude [ft] 32.3467
Outside Ambient Temperature [degC] 15
Rotor Rotational Speed [rpm] 257.904
Rotorcraft C.G. (Buttline Station) [inch] 0
Rotorcraft C.G. (Fuselage Station) [inch] 358
Rotorcraft C.G. (x,y,z) in I-frame [ft] 0 0 -32.3467
Rotorcraft FCS on/off Status [nd] 1
Rotorcraft Gross Weight [lbf] 15922.3
Rotorcraft Wheel Height above Deck [ft] 26.83
Ship C.G. (x,y,z) in I-Frame [ft] 0 0 0
Ship Course from North [deg] 0
Ship Forward Speed [knots] 20
Ship Landing Spot ID [nd] 1
Ship Pitch Attitude [deg] 0
Ship Roll Attitude [deg] 0
Ship Turbulence Intensity Factor [nd] 1
Wind Azimuth from North [deg] 0
Wind Magnitude (horizontal) [knots] 0
Apply
Close
Help...


Test Case ID
Case Description
Sweep Option 0: Ship Speed
Min Max Delta
Ship Forward Speed (knots) 10 30 10 0: Uniform Trim to limit
Ship Course from North (deg) -20 20 20 0: Uniform
Ambient Wind Speed (knots) 0 30 10 0: Uniform Trim to limit
Ambient Wind Azimuth (deg) -30 30 10 0: Uniform
Wind Over Deck Speed (knots) 10 30 10 0: Uniform Trim to limit
Wind Over Deck Azimuth (deg) 160 240 20 0: Uniform
Rotorcrafdt Heading (deg) 0 60 30 0: Uniform
MEMO: Fri Jul 20 12:33:12 PDT 200
Ok
Apply
Results ...
Standard Plot
Comparison Plot ...
Close


Criteria Range
Roll Attitude Limit Range (deg) -45 45
Pitch Attitude Limit Range (deg) -20 20
Total engine max. cont. power rating (hp) 2800.0
Land-based sideward flight limit (knots) 35
Land-based rearward flight limit (knots) 35
Criteria Margin
Roll Attitude Margin (deg) 10
Pitch Attitude Margin (deg) 10
Long. Stick Margin (percent) 10
Lat. Stick Margin (percent) 10
Coll. Stick Margin (percent) 10
Pedal Margin (percent) 10
Power Margin (percent) 10
Apply
Plot
Close

Sample DI Analytic Envelope



VV&A

- **Required** - Sanity check of model structure
- **Verification** - Was model programmed and/or implemented correctly?
- **Validation** - How close does model compare with real world data?
- **Accreditation** - Process of approving model for specific applications
- **Built-in Validation Options** - Test data and model criteria comparison, & model data format

Summary

- Conventional T&E methodologies applied to early aircraft were not designed to share information
- The complexity of modern aircraft combined with limited budgets dictates a virtual systems engineering approach to support future T&E
- An integrated systems approach to T&E could be used to not only help reduce the cost and cycle time of testing, but would also support the issues of interoperability and systems of systems testing